REMARKS

This paper is submitted in response to the Office Action for the above-identified application mailed July 17, 2003.

Under cover of the Office Action, independent Claims 20 and 29 and companion dependent Claims 21-26 and 30-34 were rejected under 35 U.S.C. Sec. 103 for being obvious over U.S. Patent No, 6,061,065 to Nagasawa in view of U.S. Patent No. 6,552,726 to Hurley. Dependent Claims 27 and 35 were rejected over the above combination further in view of Shirman, U.S. Patent No. 6,151,029. Dependent Claims 28 and 36 were rejected over the primary combination further in view of Shirman and U.S. Patent No. 5,369,737 to Gholizadeh.[1]

It was further stated in the Office Action that Claims 37-39 are in an allowable form. The Applicant thanks the Examiner for the favorable review of these claims. However, for the reasons set forth below, the rejection of the remaining claims is respectfully traversed.

Initially, under cover of this Office Action the Applicant has minor changes to Claims 20, 23, 27 and 29-34. These changes are made to ensure that the claims particularly point out and distinctly claim the invention to which this application is directed. The changes do not introduce new matter for consideration.

Turning to the prior art rejection, it is noted that the Hurley patent has a filing date of July 17, 1998. The earliest possible filing date of the Shirman patent is August 22, 1997.

Both the above dates are ***after*** the August 20, 1997 filing date of British Patent Application No. 9717656.4, the

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[1] The Office Action did not explicitly state that the Hurley patent was applied against Claims 27, 28, 35 and 36. However, in a telephone call on October 9, 2003, the Examiner stated that these claims, given their dependency from the independent claims against which the Hurley patent was applied, are likewise rejected in view of the Hurley Patent. The Applicant thanks the Examiner for the consideration shown in the telephone conversation.

application from which this application claims priority under 35 U.S.C. Sec. 119. A copy of the '656.4 British Application, including its Filing Receipt, is enclosed.

Applicant's invention as recited by independent Claims 20 and 29 is described at pages 5-8 and illustrated in Figures 1 and 3 of the '656.4 British application.

Since the application from which this application claims priority has a priority filing date ***before*** the filing dates of the applications upon which the Hurley and Shirman patents are based, these patents should not be applied against the present application.

It is acknowledged that the *Manual of Patent Examining Procedure*, Sec 201.14(b) states that a certified copy of the underlying foreign application must be filed in order to properly assert a priority claim. According to the Form PCT/DO/EO/903 the Patent and Trademark Office mailed for this application on April 14, 2000, copy enclosed, the Office already has in its possession a certified copy of the '656.4 British Application[2]. Therefore, given that the Office has a certified copy of this application and the Applicant asserted the priority claim in his Declaration, it is submitted the priority claim for this application has been **successfully perfected**.

Therefore, the Hurley and Shirman patents should be withdrawn as references against this application.

Accordingly, the available prior art does not show that the invention recited by Claims 20 and 29 is obvious, let alone anticipated. Therefore, it is submitted that these claims are directed to an invention that is entitled to patent protection.

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[2] If the Office's file for this application does not have this document, a call to the undersigned will result in prompt delivery of a replacement copy.

The dependent claims are all allowable at least because they depend from allowable independent claims.

It is acknowledged that this paper is being submitted in response to a final Office Action. The claim amendments do not raise any new matters for review. This Response primarily points out why two of the references used to reject the claims should not have been applied. It is submitted that this is a good reason as to why this Response should be entered.

The entry of this Response will place the claims of this application in an allowable form. Since the claims, as well as the other parts of this application, are in an allowable state, the Applicant now courteously solicits prompt issuance of a Notice of Allowance.

Respectfully submitted,

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Your Ref. : AJR/38953

21 August 1997

PATENT APPLICATION NUMBER 9717656.4

The Patent Office confirms receipt of a request for grant of a patent, details of which have been recorded as follows :

Filing Date (See Note)	:	20-AUG-97
Applicants	:	VideoLogic Limited
Description (No.of Sheets)	:	9
Claims (No.of Sheets)	:	2
Drawings (No.of Sheets)	:	2+2
Abstract	:	None
Statement of Inventorship (Form 7/77)	:	None
Request for Search (Form 9/77)	:	Yes
Request for Examination (Form 10/77)	:	None
Priority Documents	:	None
Translation of Priority Documents	:	None
Divisional of Application	:	None
Divisional Date Claimed	:	
Other Attachments Received	:	None

The application number included in the heading above should be quoted on all correspondence with The Patent Office.

Any queries on this receipt should be addressed to Mrs Lynne Payne, tel 01633 814570.

Note : The above filing date is provisional and may need to be amended if the provisions of section 15(1) of the Patents Act 1977 are not met.

SHADING THREE DIMENSIONAL COMPUTER GRAPHICS IMAGES

This invention relates to the shading of three dimensional computer graphic images, and especially to graphic images generated in real time.

Many three dimensional computer graphics images are modelled with perfectly flat or smooth surfaces. Usually these surfaces are constructed from a plurality of small triangles to which is applied either flat shading, or smooth shading as described in "Transactions on Computers" IEEE-20 (6) June 1971 pp 623 to 629 by Gouraud, H., graduated shading, or, less frequently Phong shading from CACM 18(6)June 1975 pp 311 to 317 "Illumination for Computer Generated Pictures". Visual detail may be applied to these surfaces via the application of textures. These textures are generally two dimensional images and the process is similar to having an image painted onto a perfectly smooth wall. It does not model any surface roughness or any shading effects which might arise therefrom.

In computer graphics the way in which light interacts with the surface is referred to as shading. One of the simpler models used for shading is known as Lambert or diffuse shading. It is computed as a function of the direction of the light illuminating the surface and the orientation of that surface. The orientation is represented by a unit vector perpendicular to the surface (a surface normal). The light direction is also preferably assumed to be a unit vector which points from the surface to the point of illumination. In the case of flat shading the surface normal is considered to be constant across the entire surface. With Gouraud shading three surface normals defined at the vertices of each triangle are used. The shading at the vertices of the triangles is calculated from these normals. These shading values are then

interpolated across th entire surface. This is a satisfactory approximation in many cases. However, it does lead to shading problems such as mach banding and problems with specular highlights.

Phong shading gives a superior result to this because it interpolates the surface normally across the triangle and then recalculates the shading at each pixel. However, both of these per pixel operations are considered to be relatively expensive computationally and, therefore, Gouraud shading is therefore more commonly used.

3D computer graphics often makes use of specular shading in addition to diffuse lighting. Specular shading is the modelling of glossy refections of lights. In both types of shading a common basis for the calculation of the shading to be applied is a vector dot product raised to a power. This is shown in equation 1 below.

$$((1-h)+h.\vec{D}_{light}.\vec{D}_{normal})^p$$

In "simulation of wrinkled surfaces" by Blinn, J.F. in Siggaph 1978 pp 286 to 292 there is proposed the concept of bump mapping. This uses an adaptation of texturing to deviate surfaces normal on a pixel by pixel basis. The texture data used to form the derivation of the normal is referred to as the bump map.
Although the position of the surface is not actually moved in 3D graphic space it appears rough because shading is performed with a surface normal which moves in direction as the surface is traversed.

This process is known as surface normal perturbation. What is stored in the bump map is an amount by which the surface normal is to deviate from its previous value. Thus, in order to compute the shading applied to a surface

it is necessary to retrieve data about the deviation of the surface normal from the bump map prior to applying this deviation to the surface normal. The surface normal then has to be renormalised in dependence on the orientation of the surface to which it is applied. The shading calculation is then performed.

The effect of this leads to realistic dynamic changes in shading as a light source moves relative to the surface. However, computationally the scheme is approximately the same as that of Phong shading and so to date has been restricted to non-real time applications.

We have appreciated that an effect similar to that proposed by Blinn can be implemented with much less computational power thus enabling realistic changes of shading to be implemented in real time.

Preferably this is implemented in addition to the usual 3D computer graphics rendering systems which are in common usage for texturing and shading.

Preferably, after a surface has been rendered the bump map effects are applied as an additional pass over the surface. For each image element or pixel a bump map texture element is obtained in a way identical to the usual texturing operation. Lighting values are also interpolated across the surface on a pixel by pixel basis from the light sources in use. The lighting values for a particular pixel are combined with the bump map texel (texture element) to produce an alpha value and a colour and thereby look identical to the usual output of the texturing engine. These are then supplied to the usual blending units to apply the texture. Unlike the approach taken by Blinn each texel of the bump map stores the actual direction of the surface normal after perturbation rather than the displacements of the surface normal.

These normals are given in the surface's coordinate system which is preferably the polar coordinate system. Lighting values are similarly expressed in terms relative to the surface's coordinate system.

The invention is defined with more precision in the appended claims to which reference should now be made.

A preferred embodiment of the invention will now be described in detail by way of example with reference to the accompanying drawings in which:

Figure 1 is a block diagram of circuitry a first embodiment of the invention;

Figure 2 is a schematic diagram showing the surface normal and its coordinate system; and

Figure 3 is a block diagram of the bump map hardware of Figure 1.

Figure 4 is a schematic diagram showing the surface normal and a Cartesian coordinate representation system in contrast with the polar coordinates of figure 2;

Figure 5 shows schematically a linear filter applied to texels;

As described above this invention relates to computer 3D graphics rendering systems and is applicable but not restricted to hardware based rendering systems. A hardware based system is described here by way of example.

The first embodiment of the invention shown in Figure 1 comprises a modified conventional 3D rendering system. Conventional 3D texture hardware 2 is used to apply

texture to the image and rending hardware 4 then shades the textured image. Conventionally a single connection is provided between these two hardware blocks.

In the modified system of Figure 1 a store 6 is used for surface bump map direction parameters for a number of different bump maps. This stores a set of surface normals pointing in different directions in dependence on their location in the bump map. These are called up by the bump map hardware 8 which combines the lighting values for a particular pixel with the bump map data from the store 6 to produce an alpha value and a colour. These are identical to the usual output of the 3D texture hardware 2 and are then supplied to the usual blending unit which uses the alpha value to combine the colour with existing colour at that pixel in proportions dependent on the alpha value (alpha is between 0 and 1).

Thus, the system applies surface normal perturbation effects to a surface as one additional single pass to modify the existing texturing and shading. When it is determined that for a given surface and picture element "pixel" that a bump map pass is required, then the appropriate surface parameters are obtained for that surface. The surface normal for that pixel is determined by accessing the bump map texture associated with the surface in a similar manner to existing texture mapping methods. A direction parameter is also calculated for the pixel by interpolation. This is similar to the RGB interpolation performed for Gouraud shading. Thus the alpha value and colour value are supplied to the blending unit.

The bump map surface normals stored in store 6 are encoded in polar coordinate as shown in Figure 2. Angle S represents the elevation of the surface normal and goes from 0 to 90°. Angle R is the rotation of the surface

normal and goes from 0 to 360°. As the surface normal is a unit vector the length value is always I and so it is not required to store this. Thus a saving on memory is achieved.

In one embodiment of the invention the per surface direction parameters for the lighting sources are also encoded in spherical coordinates with parameters T ranging from 0 to 90° and Q ranging from 0 to 360°. The dot product power function of equation 1 would then be implementated as shown below in equation 2.

$$((1\text{-}h)+h(\sin(S)\sin(T)+\cos(S)\cos(T)\cos(R\text{-}Q)))^{p}$$

The parameter H is a weighting value that lies in the range 0 to 1. The surface direction parameters T and Q can be interpolated in a manner similar to that used in Gouraud shading.

Another embodiment would include the T and H per surface direction parameters as parameters k_1, k_2, k_3 thus giving the dot product power function shown below in equation 3.

$$(k_1+k_2\sin(S)+k_3\cos(S)\cos(\mathrm{R\text{-}Q}))^{p}$$

Typically these values would be calculated as shown below in equation 4.

$$k_1=(1\text{-}h);\quad k_2=h\sin(T);\quad k_3=h\cos(T);$$

This gives further flexibility as well as reducing the complexity of the implementation in hardware.

An embodiment of the invention using the equation shown in equation 3 is illustrated in Figure 3.

The elevation angle S for the surface normal is first passed to a sine and cosine unit 10 which computes the sine and cosine of the elevation and applies these to multipliers 12 and 14 where they are combined with lighting parameters k_2 and k_3. At the same time, the rotation angle R of the surface normal has the rotation angle Q of the lighting value subtracted from it in subtracter 16. The cosine of this angle is then derived in cosine unit 18. The output of this unit is unsigned and is fed to a multiplier 20 where it serves to multiply the output of multiplier 14. The output of multiplier 12 is then passed to an adder 22 where it is added to lighting parameter k_1.

The output of adder 22 and multiplier 20 are then passed to an add/subtract unit 24. A signed bit 26 supplied by the cosine unit 18 determines whether the adder adds or subtracts the output of multiplier 20 from the output of adder 22.

The output of this adder is a signed 11 bit number which is supplied to a clamping unit which reduces it to the range 0 to 255 (8 bits) and outputs this to a power unit 30 which raises its value to a power p which is supplied to the power unit.

In this embodiment the S and R values obtained from the bump map texture are both encoded as 8 bit unsigned numbers. For S 0 to 255 represents angles of 0 to almost 90° (256 would represent 90° exactly) while for R 0 to 255 represents angles of 0 to almost 360° (256 would represent 360° exactly).

The units of Figure 3 show the number of bits and whether or not those integers are signed or unsigned. U x represents an unsigned x bit integer. While S x represents a signed x bit integer.

Thus, the alpha output to the blending unit is provided along with a colour from the existing 3D texture hardware 2. The existing colour and the new colour are then combined in the blending hardware 4 to produce a new value for that particular pixel.

Using this method has several advantages. Firstly, storage of surface normals as polar co-ordinates makes the bump map data compact compared to the method of Blinn which used surface normal displacements. Furthermore, renormalisation of the surface normals is not necessary because of the nature of storage as surface normals. Finally, interpolation of light direction is a relatively straight forward calculation to be performed since in most scenes there will only be a small number of light sources on which the lighting direction has to be based. This enables rendering to be performed in real time.

The bump mapping technique described above has some shortcomings. These are:

1. Interpolation of the lighting direction given at each vertex is 'tricky', as the direction is specified in polar coordinates. Although polar coordinates allow greater precision with the direction specification and do not need normalisation, to perform the interpolation requires significant modification to the iterator units. Because of this, the hardware can assume that the light direction is constant across each polygon. This effectively eliminates Phong shading.

2. For similar reason, bilinear texturing computations are more complicated. Although some modifications were made to perform angular bilinear, the actual results are not ideal.

3. The system cannot model light directions that are 'below' the horizon - these must be converted to an approximate direction that is on the horizon.

4. The software interface bears little resemblance to the actual hardware interface. This means extra work for the drivers or at least to the application.

The second embodiment described below addresses these issues. To do this there are two major changes to the implementation:

1. The light direction vector is now specified in "X,Y,Z" fixed point coordinates. This is very similar to a typical software interface, in which the light direction vector is given in floating point coordinates. Ideally, the floating point vector will have been normalised.

2. The bump map texel directions are also now specified in Cartesian coordinates, except that one component can be eliminated due to redundancy. We thus only store "X" and "Z" per texel.

The idea of specifying bumps and light directions in a local vertex coordinate system remains the same. Converting a height map to the new format is much easier than the old, since no trigonometry is required. Additionally, the new technique includes a 'glossiness' parameter that allows the modelling of specular highlights.

As in the first embodiment each texel stores the 'angle' or 'surface normal' of the bumpy surface at that particular texel, and it is assumed that the vector can lie anywhere within a hemisphere, as shown in figure 4.

We are not interested in the length of this vector (as it is assumed to be of unit length) but only in its angle. In the first embodiment, this vector was stored using polar coordinates, however these are a nuisance to interpolate.

In the second embodiment, the vector is represented in the more usual Cartesian coordinate system. The obvious way to store this would be X,Y,Z, where Y is always positive, and X & Z are signed values, however, we are typically limited to only 16 bits. If, however, we scale the vector such that

$$|x_s| + y_s + |z_s| = 1$$

then there is no need to store the Y component at all, since it can be derived from the other two values. Note that this vector is no longer of unit length. Also all components of this vector are <=1, and that the length of this scaled vector is also <=1.

Expressing this in terms of a 16 bit texel, we would have the following:

```
UNIT8 TexelX, TexelY;

Texelx = ((int) (Xscaled * 127.0f)) + 127;
TexelZ = ((int) (Zscaled * 127.0f)) + 127;
```

This packs X and Z as ***offset*** 8 bit values. That is, a value of 0 represents $^{-127}/_{127}$, while 254 represents $^{+127}/_{127}$. We use this notation rather than the usual 2's complement to make the bilinear interpolation straight-forward.

To extract the X,Y and Z components 'in the hardware', we do...

```
INT9  BumpX, BumpZ;
UINT8 BumpY;

BumpX = (TexelX - 127)* 2;
BumpZ = (TexelZ - 127)* 2;
BumpY = 255 - ABS (BumpX) - ABS(BumpZ);
```

We are guaranteed that Y is positive as (ABS(BumpX)+ABS(BumpZ)) must be <= 255. (The above could probably be expressed better).

TexelX and TexelZ can be the results from the linear/bilinear/trilinear filtering.

One of the problems with the first embodiment is the behaviour of the bilinear filtering. With angles, there is a problem with wrapping around or taking the shortest interpolation path. This is eliminated with the X/Z scheme.

The interpolation is performed with just the TexelX and TexelZ components, and the Y is calculated from the filtered result. Since these values are in the range 0..255, the standard RGB filtering hardware is directly applicable. For the following examples, only a linear 'filter' will be used since both bilinear and trilinear are repeated linears.

Figure 5 shows a view from above looking down on the bump direction hemisphere. The dotted diamond shape represents the limits of the scaled X and Z values, which when re-normalised with the computed Y value would stretch out to the boundary of the hemisphere. Three example linear interpolations in X and Z are shown.

For *Path A*, the interpolation would result in an angle that goes up and over the pole of the hemisphere - which is ideal. The previous method would have chosen a path

that ran in a circle 'copying' the circumference. For *Path B*, the interpolation would stay close to the circumference of the hemisphere. *Path C*, should also result in a sensible interpolation with a rise and fall in the 'Y' component.

The only likely quibble with this scheme is that the rate of change of the angle may not be constant, but this seems very minor.

To prevent loss of accuracy with fixed point implementations, it is important that the length of the vector should not decrease too greatly, since in a fixed point system, bits will be lost. In this encoding , the minimum length would occur when $|x_s| = y_s = |z_s| = 1/3$, resulting in a length of $1/3$. This loses less than 2 bits of accuracy, and so is acceptable.

There are two things we must guard against. The first is that not all possible combinations of 'texel' contents are valid. Since we have specified that $|x_s| + y_s + |z_s| = 1$ a texel that has $|x_s| + |z_s| > 1$ is clearly invalid. We must therefore, protect against such occurrences.

The second point is that even if the original texels are valid, there is a small chance that the bilinear unit will produce X and Z values which also *just* exceed these legal values.

As with the alternate bump format the light direction vector is stored in Cartesian coordinates. The only space we have available is the OffsetRGB/original-BumpK values, as an example we may have 8 bits for each of the X, Y, and Z components. These values all need to be signed, and to keep accuracy, *it is assumed that the light direction vector is normalised before conversion to integer.* The per-vertex values would therefore be calculated from...

```
int8 VertX, VertY, VertZ;

VertLightX = ((int) (LightDir(0) * 127.0f)) & 0xFF;
VertLightY = ((int) (LightDir(1) * 127.0f)) & 0xFF;
VertLightZ = ((int) (LightDir(2) * 127.0f)) & 0xFF;
```

Since we are assuming that each vertex light vector is of unit length and because we are using 'linear' interpolation, the vector for a particular pixel will have a length that is <=1. As with the bump map, it is important that the in-between vectors are not too short or else too much accuracy will be lost.

If we assume that the maximum sensible angle difference will be 120°, then the shortest vector will be sin(30°) = ½. We will therefore only lose about 1 bit of accuracy due to the shortening of vectors.

To have the chance of 'smooth' animation, it is important that small changes in light direction can be modelled. This will be of maximum importance near where the light direction = (0,1,0) ie. on the horizon so examining the minimum integer variation that seems possible we get [2,254,0]. This appears to be about an angle of 0.1 degrees, which seems small enough.

The shading "dot product" computation is much simpler than it is with polar coordinates and is implemented in a well known manner.

To simulate glossy highlights, a 'power' function is usually applied to the dot product so that bright areas become concentrated. The typical Phong lighting model raises the dot product to an arbitrary power, but this is too expensive to implement in hardware.

A cheaper, but more than satisfactory function is to use a quadratic approximation as shown below.

Let X be the result of the dot product,

C be a 'fixed point' 8 bit concentration value, where C=0 (==0.0) gives a linear output, and C=255 (==1.0) gives maximum concentration.

We compute...

- k=C+8; *(k is a 9 bit value with 3 bits of fraction)*
- L=MAX(0, 1023-(k*(1023-X)>> 3)); *L is a 10 bit fractional value*
- Q=(L*L)>>10 *Q is a 10 bit fractional value*
- P=L+C*(Q-L)>>8;

P is then the fixed point result of the power function. Note that Q≤L and so the final calculation will require signed maths.

In total, the highlight function will require 5 add/subtracts and 3 multiplies, although a couple of these are rather simple degenerate cases.

Thus, it will be appreciated that preferred embodiments of the present invention provide a system which enables textured surfaces to be shaded much more efficiently than has been possible.

CLAIMS

1. A method for shading a three dimensional textured computer graphic image comprising the steps of:

providing data defining the three dimensional computer graphic image;

providing a set of surface normal vectors corresponding to the texture data for the image wherein the surface normal vectors are stored in a local coordinate system;

providing data defining at least one light source and its direction illuminating the image wherein the light source is defined in the same local coordinate system; and,

for each pixel in the image, deriving a shading value to be applied to that pixel from the set of surface normal vectors and the light source data.

2. A method according to claim 1 in which the surface normal vectors are stored in polar coordinates.

3. A method according to claim 1 or 2 in which the light source data is stored in polar coordinates.

4. A method according to claim 1 in which the step of deriving a shading value to be applied to a pixel comprises deriving a colour value and a blending value from the light source data and combining this colour value with existing colour data from that pixel in dependence on the blending value.

5. A method according to claim 1 in which the surface normal vector is stored in Cartesian coordinates.

6. A method according to claim 1 or 5 in which the light source data is stored in Cartesian coordinates.

7. A method according to claim 5 in which for each surface normal only two of the Cartesian coordinates are stored.

8. A method according to any preceding claim comprising the step of applying a linear filter to the texture data at least once to map values to individual pixels.

9. A method according to any preceding claim including the step of applying a glossiness parameter to a pixel.

10. Apparatus for shading a three dimensional textured computer graphic image comprising:

means for providing data defining the three dimensional computer graphic image;

means for providing a set of surface normal vectors corresponding to the texture data applied to the image wherein the surface normal vectors are stored in a local coordinate system;

means for providing data defining at least one light source and its direction illuminating the image wherein the direction of the light source is provided in the same local coordinate system; and

means for deriving a shading value to be applied to each pixel in the image from the set of surface normal vectors and the light source data.

11. Apparatus according to claim 10 in which the surface normals are stored in polar coordinates.

12. Apparatus according to claim 10 or 11 in which light source data is stored in polar coordinates.

13. Apparatus according to claim 10 in which the surface normals are stored in Cartesian coordinates.

14. Apparatus according to claim 10 or 13 in which the light source data is stored in Cartesian coordinates.

15. Apparatus according to claim 13 in which for each surface normal only two of the Cartesian coordinates are stored.

16. Apparatus according to any of claims 10 to 15 comprising means

for applying a linear filter at least once to the texture data to map values onto individual pixels.

17. A method according to claim 10 in which means for deriving a shading value to be applied to a pixel comprises means for deriving a colour value and a blending value from the light source data and means for combining the colour value with an existing colour value in dependence on the blending value.

ABSTRACT

A three dimensional textured computer graphic image is shaded by firstly providing data which defines the computer graphic image. Textured data is then applied to that image. A set of surface normal vectors corresponding to the texture data are then applied to the image and data defining at least one light source which illuminates the image is also provided. For each pixel in the image a shading value is derived to be applied to that pixel from the set of surface normal vectors and the light source data.

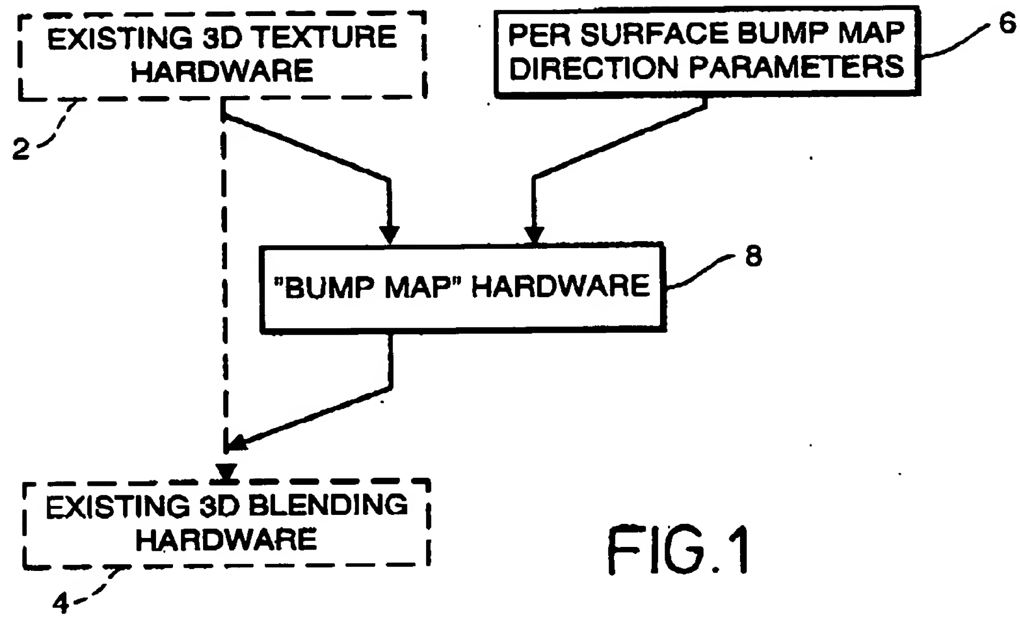

EXISTING 3D TEXTURE HARDWARE
PER SURFACE BUMP MAP DIRECTION PARAMETERS
6
2
"BUMP MAP" HARDWARE
8
EXISTING 3D BLENDING HARDWARE
4

FIG.1

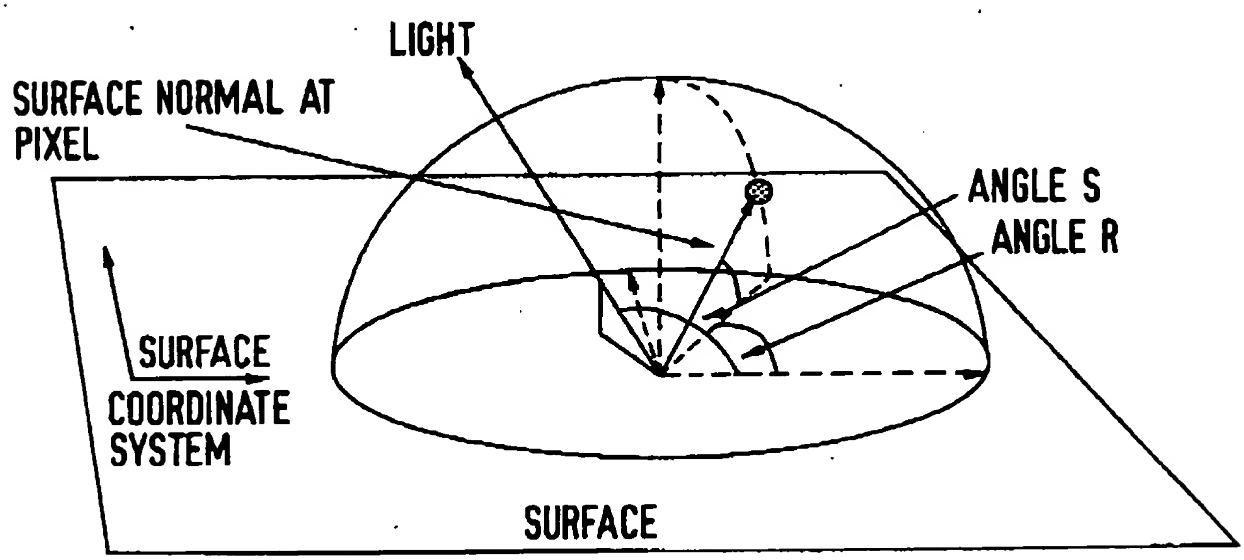
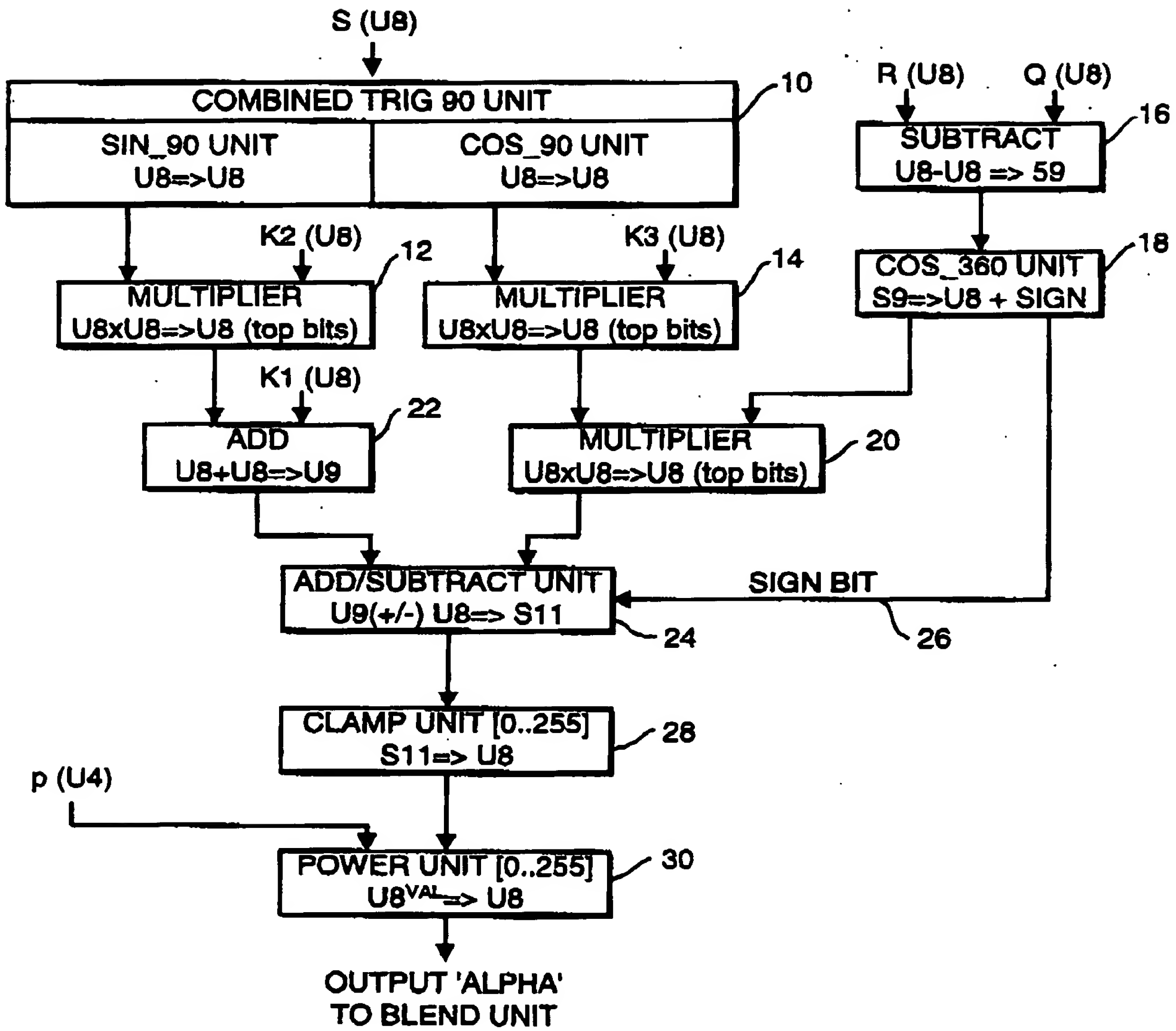
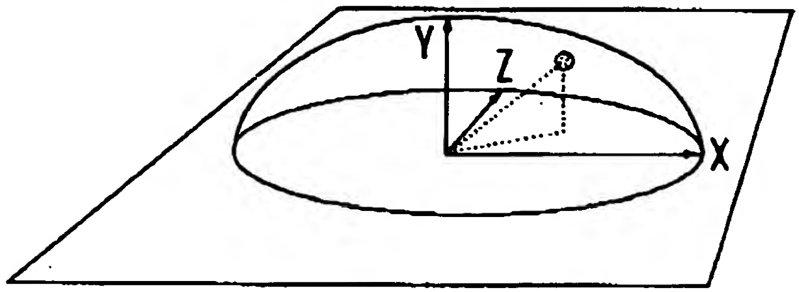

LIGHT
SURFACE NORMAL AT PIXEL
ANGLE S
ANGLE R
SURFACE COORDINATE SYSTEM
SURFACE

FIG.2



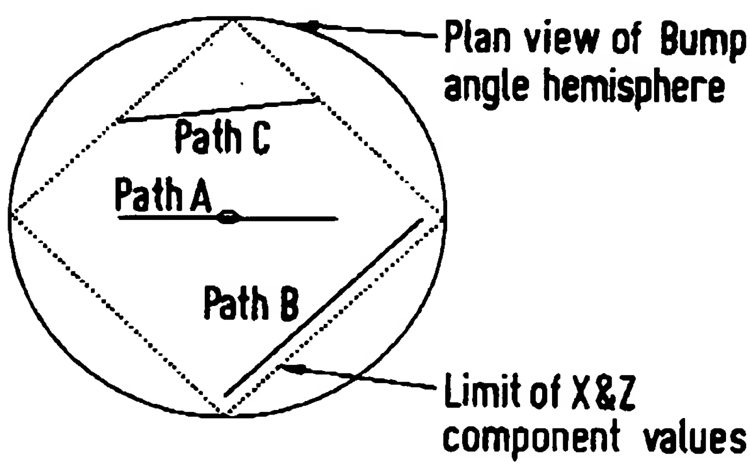
S (U8)
COMBINED TRIG 90 UNIT
SIN_90 UNIT U8=>U8
COS_90 UNIT U8=>U8
10
R (U8)
Q (U8)
SUBTRACT U8-U8 => S9
16
K2 (U8)
12
K3 (U8)
14
MULTIPLIER U8xU8=>U8 (top bits)
MULTIPLIER U8xU8=>U8 (top bits)
COS_360 UNIT S9=>U8 + SIGN
18
K1 (U8)
22
ADD U8+U8=>U9
MULTIPLIER U8xU8=>U8 (top bits)
20
ADD/SUBTRACT UNIT U9(+/-) U8=> S11
SIGN BIT
24
26
CLAMP UNIT [0..255] S11=> U8
28
p (U4)
POWER UNIT [0..255] U8VAL=> U8
30
OUTPUT 'ALPHA' TO BLEND UNIT

FIG.3



Y
Z
X

FIG.4



Plan view of Bump angle hemisphere
Path C
Path A
Path B
Limit of X&Z component values

FIG.5

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UNITED STATES DEPARTMENT OF COMMERCE
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U.S. APPLICATION NO.	FIRST NAMED APPLICANT	ATTY. DOCKET NO.
09/486012	FENNEY	S R & G CASE 3 05

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DNT____ DGB____ RJT____
TFC____ MLM____ DSG____
TBC____ LLC____ BRT____

MAY 27 2000

SBW____ LJW____ KC ____
CMG PMG GMG
FILE

INTERNATIONAL APPLICATION NO.	
PCT/GB98/02488	
I.A. FILING DATE	PRIORITY DATE
19 AUG 98	20 AUG 97

DATE MAILED: 24 MAY 2000

NOTIFICATION OF ACCEPTANCE OF APPLICATION UNDER 35 U.S.C. 371 AND 37 CFR 1.494 OR 1.495

1. The applicant is hereby advised that the United States Patent and Trademark Office in its capacity as ☐ a Designated Office (37 CFR 1.494), ☒ an Elected Office (37 CFR 1.495), has determined that the above identified international application has met the requirements of 35 U.S.C. 371, and is **ACCEPTED** for national patentability examination in the United States Patent and Trademark Office.

2. The United States Application Number assigned to the application is shown above and the relevant dates are:

15 May 2000	15 May 2000
35 U.S.C. 102(e) DATE	DATE OF RECEIPT OF 35 U.S.C. 371 REQUIREMENTS

A Filing Receipt (PTO-103X) will be issued for the present application in due course. **THE DATE APPEARING ON THE FILING RECEIPT AS THE "FILING DATE" IS THE DATE ON WHICH THE LAST OF THE 35 U.S.C. 371(C) REQUIREMENTS HAS BEEN RECEIVED IN THE OFFICE. THIS DATE IS SHOWN ABOVE.** *The filing date of the above identified application is the international filing date of the international application (Article 11(3) and 35 U.S.C. 363).* Once the Filing Receipt has been received, send all correspondence to the Group Art Unit designated thereon.

3. ☒ A request for immediate examination under 35 U.S.C. 371(f) was received on 17 February 2000 and the application will be examined in turn.

4. The following items have been received:
   - ☒ U.S. Basic National Fee.
   - ☒ Copy of the international application in:
     - ☒ a non-English language.
     - ☐ English.
   - ☒ Translation of the international application into English.
   - ☒ Oath or Declaration of inventors(s) for DO/EO/US.
   - ☐ Copy of Article 19 amendments. ☐ Translation of Article 19 amendments into English.
     The Article 19 amendments ☐ have ☐ have not been entered.
   - ☒ The International Preliminary Examination Report in English and its Annexes, if any.
   - ☒ Copy of the Annexes to the International Preliminary Examination Report (IPER).
     - ☒ Translation of Annexes to the IPER into English.
     The Annexes ☒ have ☐ have not been entered.
   - ☒ Preliminary amendment(s) filed 17 February 2000 and ____________.
   - ☐ Information Disclosure Statement(s) filed ____________ and ____________.
   - ☐ Assignment document.
   - ☐ Power of Attorney and/or Change of Address.
   - ☐ Substitute specification filed ____________.
   - ☐ Verified Statement Claiming Small Entity Status.
   - ☒ Priority Document.
   - ☒ Copy of the International Search Report ☒ and copies of the references cited therein.
   - ☐ Other:

Applicant is reminded that any communication to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above. (37 CFR 1.5)

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FORM PCT/DO/EO/903 (December 1997)